Photochemical Characterization of an L11798 High-Brightness Deuterium Lamp as a Light Source for Atmospheric Studies

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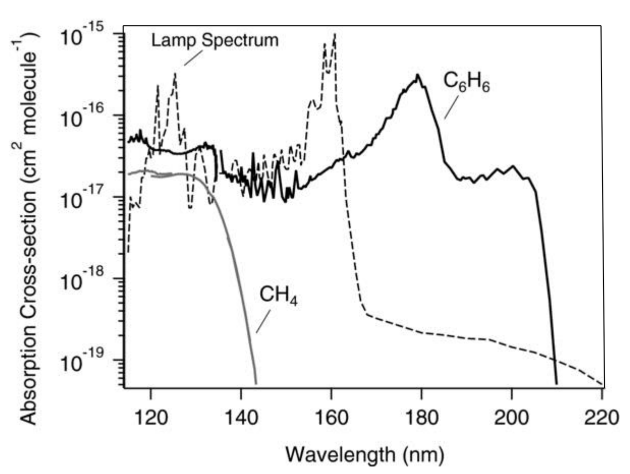
Background

In order to simulate the interaction of sunlight with planetary atmospheres, there are several important factors to be considered.

1. Spectral overlap between the excitation source and the photochemical species of interest.
2. Performance of the light source over long periods of time.
3. Performance of the lamp *in situ*.

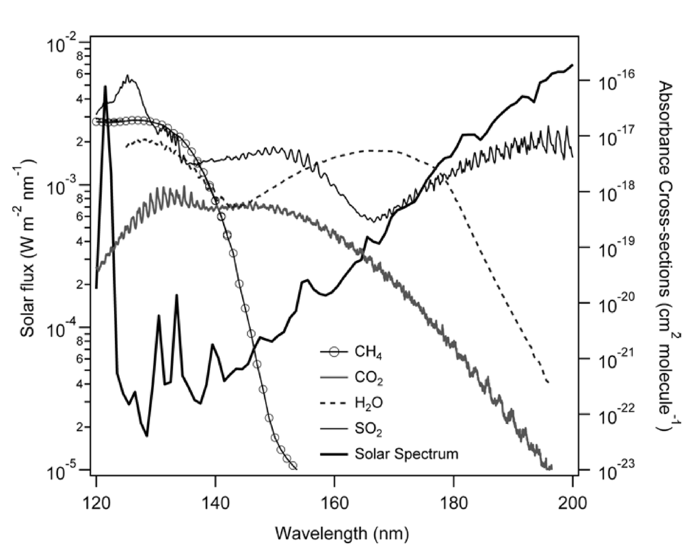
The Light Source

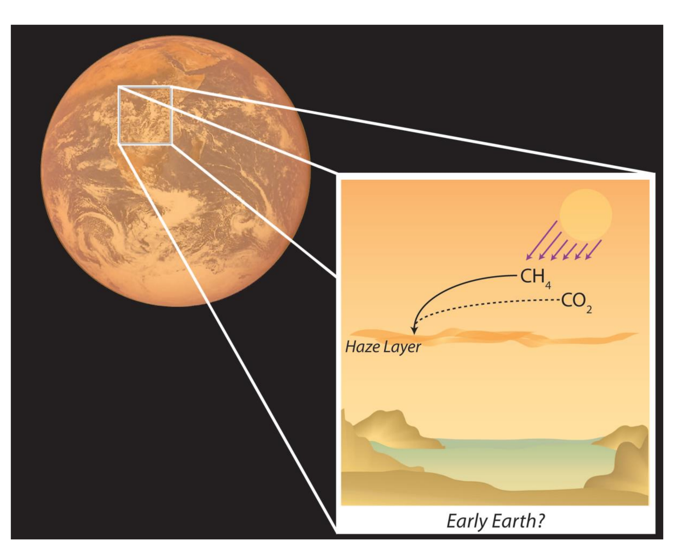
For this study, a deuterium lamp (Hamamatsu, L11798) with MgF_2 windows was used. When mounted into a vacuum chamber, this allowed for a UV range of 115 to 400 nm, with significant photon flux from 115 to 165 nm.



The spectrum of the deuterium lamp compared to methane (CH_4) and benzene (C_6H_6), two species of interest in planetary atmospheres.

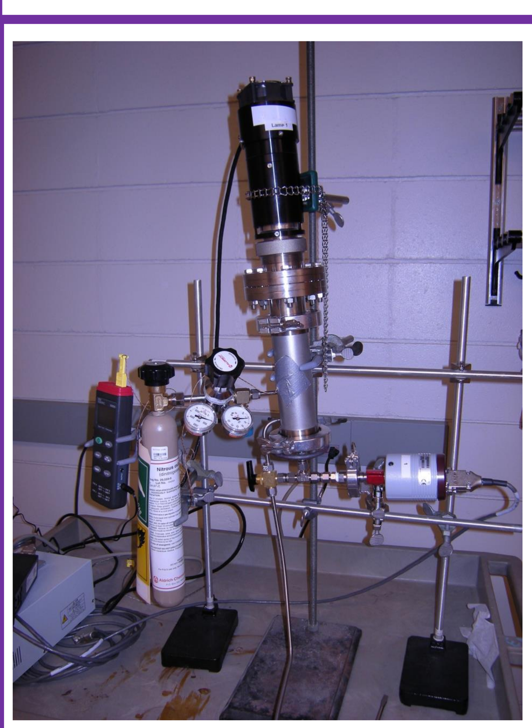
The spectrum of the lamp overlaps significantly with many species thought to be present in the atmospheres of Titan, Pluto, and the primordial Earth, making it a good photolysis source when studying formation of planetary hazes.





The spectra of several atmospheric species compared to the solar flux (left). Many of these species are thought to be responsible for photochemical haze formation (right).

Actinometry



The total VUV flux of the lamp was measured using standard N_2O actinometry. A photolysis chamber was filled with N_2O to ~10 torr. The lamp was turned on, photolyzing the gas:

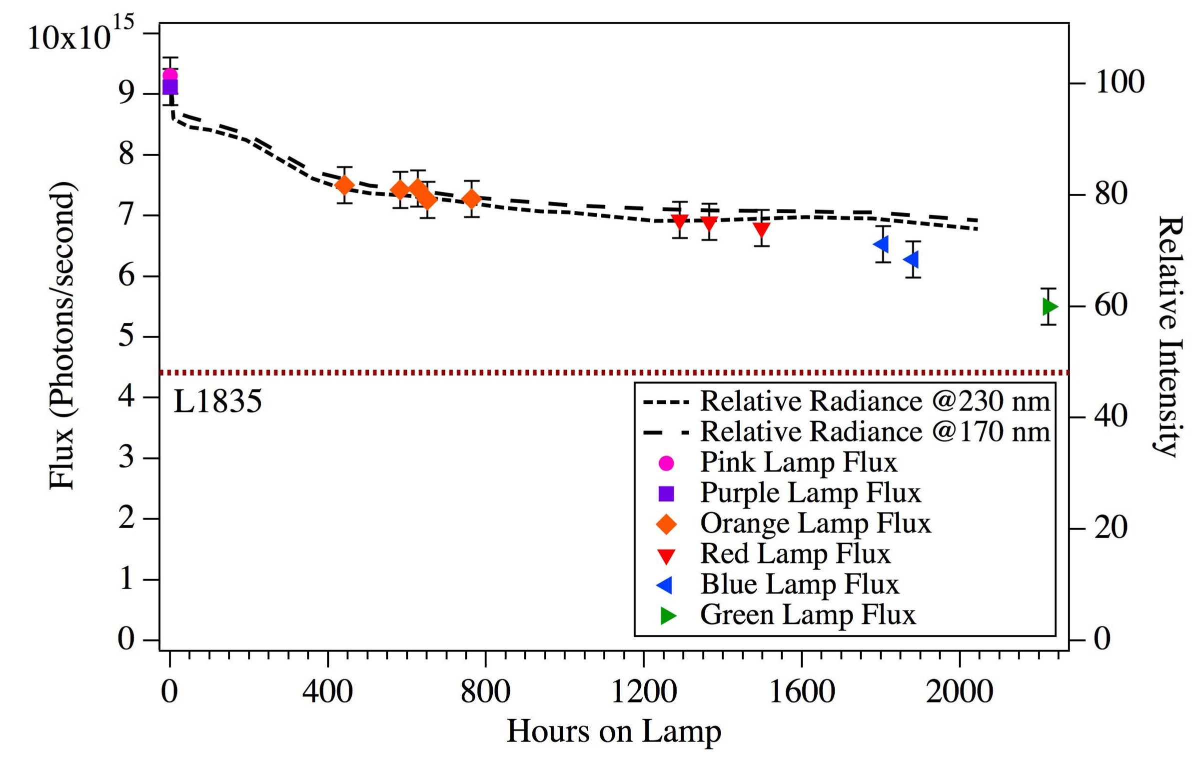
$$N_2O + h\nu \rightarrow N_2 + O_2 + NO$$

Pressure and temperature change over time was used to determine Δn. Lamp flux $\left(I = \frac{\Delta n}{\Phi_{\Delta n} \cdot \Delta t}\right)$ was then determined using a quantum yield $\Phi_{\Delta n} = 1.00 \pm 0.05$.

Lamp Performance

To preserve lamp hours, a total of six lamps with various hours of use were used to track the long term performance out to 2200+ hours.

	Age range (hours)	Flux (Photons/s)
New Lamp	0-2	$9.2\pm0.3\times10^{15}$
Middle age	400-1500	$7.2\pm0.4\times10^{15}$

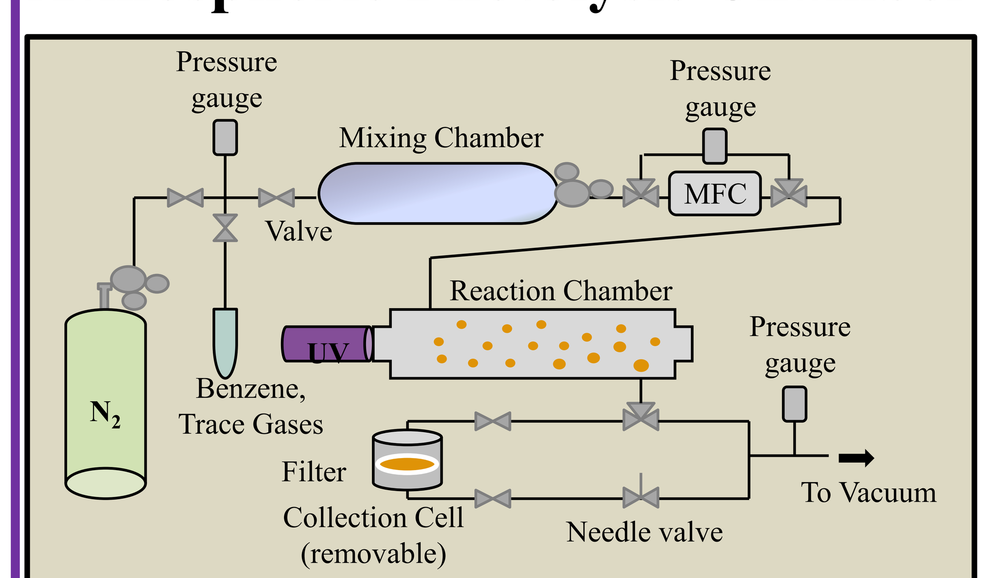


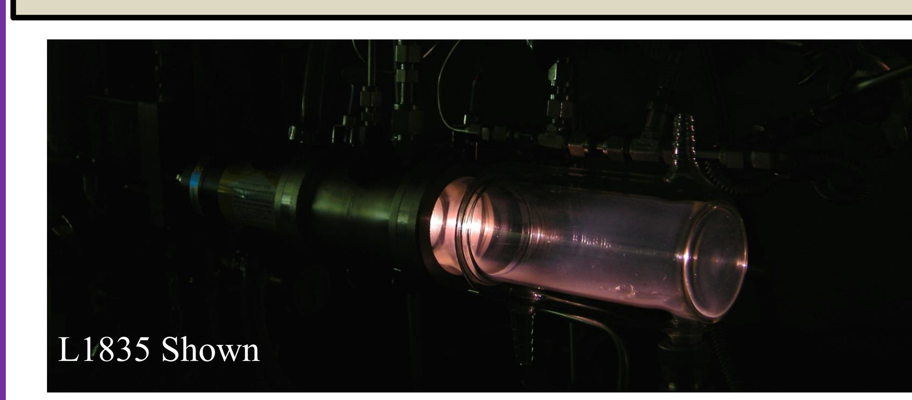
Findings

1. Performance of the six lamps is consistent with life test data provided by Hamamatsu (dashed lines) of a single lamp, indicating minimal lamp-to-lamp variation.
2. The L11798 model is ~1.5-2 times brighter then the L1835 used in previous atmospheric studies.
3. Long experiments (60-120 hours) where constant flux is important should be done with older lamps.
4. Lamp-to-lamp variation becomes more evident the more hours a lamp is used.

In Situ Performance

Atmospheric Photolysis Chamber

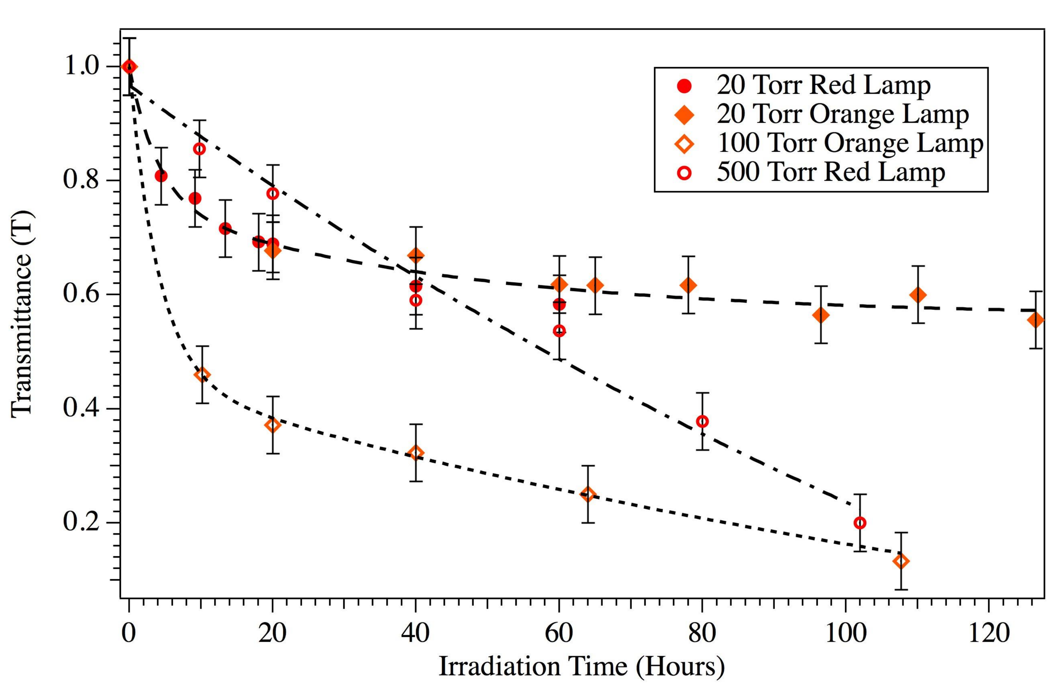




- *In situ* performance was evaluated using a gas mixture of 50 ppm benzene in nitrogen flowing at 10 sccm.
- Benzene number density was set by adjusting the pressure in the reaction vessel with a needle valve.

Chamber Pressure (Torr)	Benzene density (molecules/cm³)	Photon/Benzene Ratio within 1 cm of lamp face
20	3.2×10^{13}	45
100	1.6×10^{14}	9
500	8.1×10^{14}	1.8

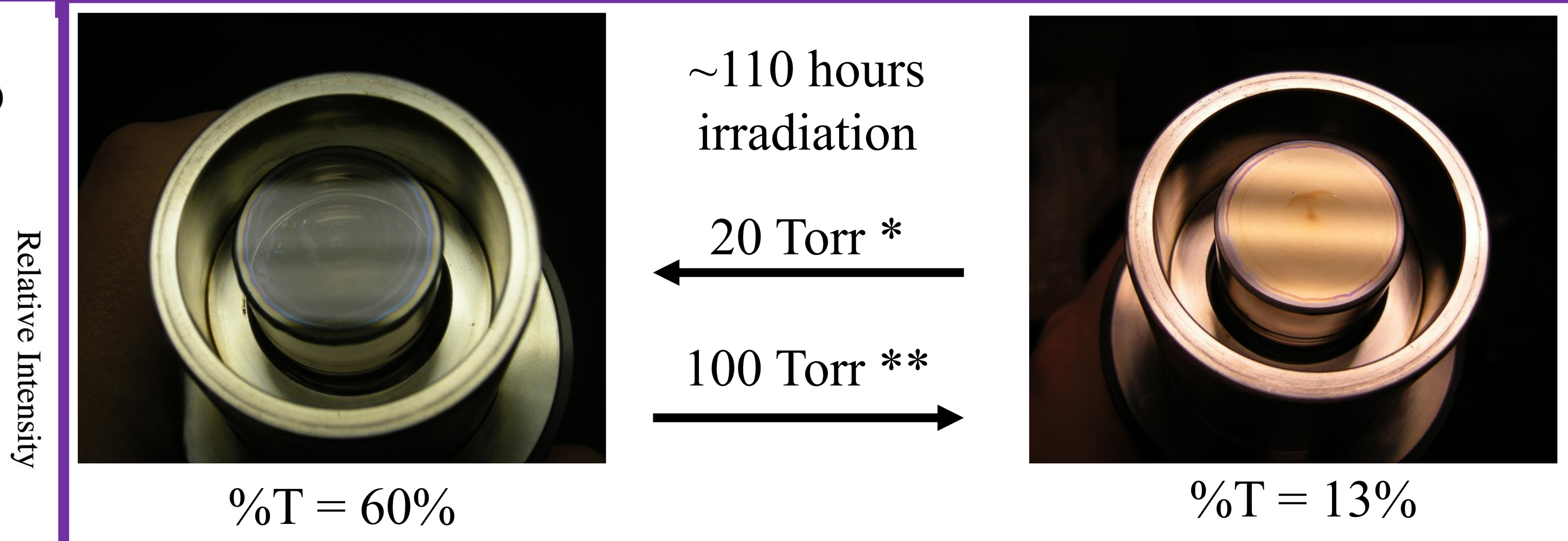
- Previous studies with Methane did not show noticeable film build up on optics.
- Benzene photolysis is ~100x more productive compared to methane.



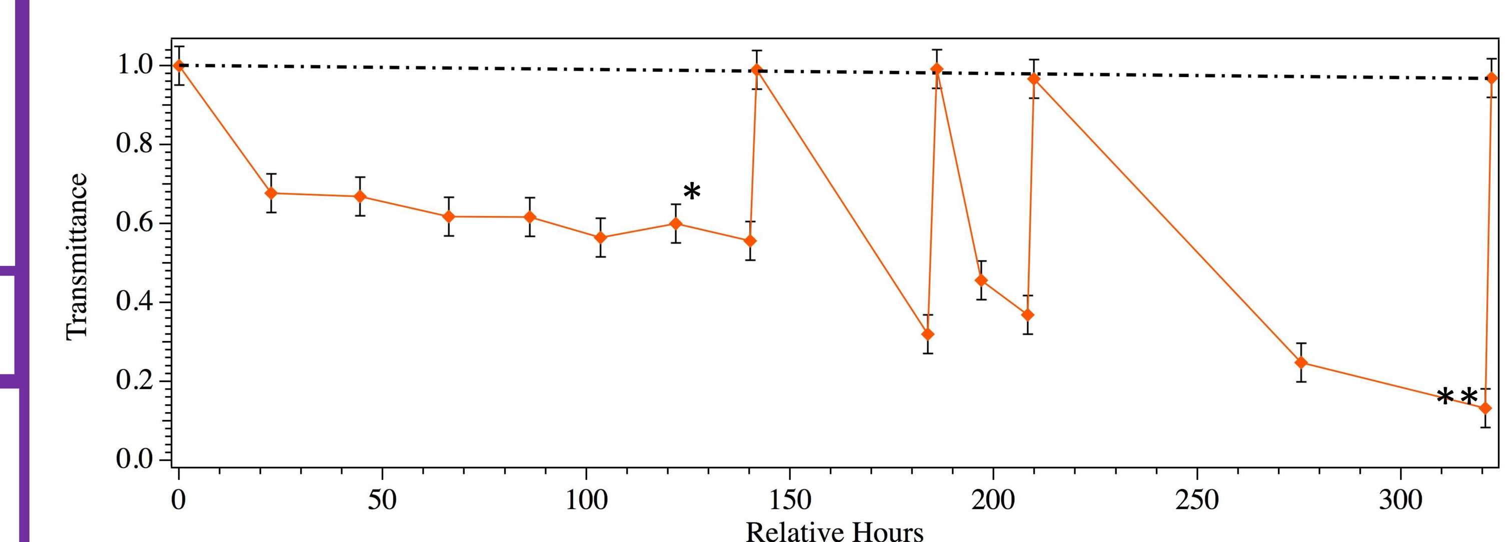
Findings

1. Benzene aerosol films cause measurable decreases in available photons.
2. Film growth causes a biexponential decay in flux at relatively short (~20 hours) time scales for high photon/benzene ratios.
3. Low photon/benzene ratios shows slower growth, but no flux plateau.

Film Removal



- Upon removal from the atmospheric chamber, even the thickest* films from the 20 torr runs were difficult to see by eye and would would usually be treated as insignificant.
- All films could be removed by alternatively wiping the MgF_2 window with lens paper dipped in dry acetone and methanol.
- Subsequent flux measurements were able to verify the removal of the organic films.



Conclusions

In conclusion, the L11798 deuterium lamp is a suitable lamp for atmospheric studies with a broad enough spectrum and sufficient VUV flux to form aerosols from simple organic compounds in laboratory simulations. Lamp-to-lamp variations are minimal in this model well past the 1000 hour lifetime guaranteed by the manufacturer. However, care should be taken when performing the long experiments required of some of these studies. High pressure/high yield experiments should include regular lamp cleaning to return to maximum flux, while mixtures that result in long term build up of films should be avoided.

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